ART. I.—*Rocks and Ore Occurrences at Bethanga and the Lower Mitta Mitta.*

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(With Plate I.).

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The author has had occasion recently to visit several places along the Mitta Mitta Valley, including Bethanga, Snowy Creek, Lightning Creek, Mount Elmo and Sandy Creek, and as there does not appear to be a large amount published as regards the character of the district beyond the somewhat general and comprehensive description that it is a metamorphic area, he thought it would be of interest to describe, as far as a fortnight's inspection would justify, some of the rocks there, and more particularly the mode of occurrence of the minerals of economic importance.

Although the greater part of the journey was over ground marked upon the Victorian Geological Map of 1902 as being metamorphic, yet the line also passes over ground marked lower silurian, between Eskdale and Lightning Creek, and of granitic rocks at Granite Flat, and its peak. A rapid journey over the so-called lower silurian exposure would not justify more than the suggestion, yet it would be desirable to raise the question as to the value of the precise geological evidence upon which the distinction has been made between the rocks at this particular part of the country and some of those of the part marked metamorphic, the resemblance being so close that in the absence of definite palæontological evidence, or of marked unconformity it is doubtful whether a distinction is legitimate. Any such evidence as the inclusion of the materials of one bed in another would be quite inadmissable in the case at Snowy Creek, where the beds so closely resemble one another. The author will also submit some reasons for viewing the line through Bethanga and the head of Little Snowy Creek, as being an axis of very old rocks, such as would make the exposure from there down to as far as the so-called hornfelds at Ensay in Gippsland, to be really that of the oldest rocks to be seen in Victoria.[1]

There are also some unmarked exposures of holocystalline rocks along the Snowy Creek, one at about seven miles to the southward of Granite Flat is of considerable size, and larger than some exposures that are marked as being granitic. But these holocrystalline rocks of the district have in most cases, even where originally intrusive, undoubtedly undergone great changes just as have the schists, and all these cases illustrate the difficulties arising out of the present official nomenclature. The holocrystalline rocks on the western bank of the Mitta Mitta, about six miles southward from Tallangatta, form one case in point, and those much to the southward in the Ensay district furnish another case.

The occurrence of gold at Lightning Creek, at the head of the Snowy Creek toward Mount Wills, presents an interest from the fact that rich alluvial was found in the creek in the early gold digging days, and that the diggers, reasoning from the analogies elsewhere, made many attempts to find the lode from which it had been supposed to have been shed. The country is, however, of the heaviest character for prospecting; with steep hillsides, narrow rapid creeks and much timber and scrub, and up to the present date that lode has never been found. The rocks are silky micaceous schists and quartzites, and it does not seem necessary to postulate the presence of a large lode to account for the coarse alluvial gold. Quite recently Mr. J. F. McCann has obtained much rich coarse gold from a spot that years ago had been cleared of its timber and had had the trestles of a large flume erected upon it by men who were prospectors by instinct, without the gold being seen at the time. This was on a spur facing to the south west at the junction of the Lightning and Snowy Creeks, and the deposit of gold was in a thin irregular seam of quartz, parallel to the ancient bedding planes of the present schists that are now nearly upright and lying about 20 degrees west of true

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1 The author would refer to the highly interesting and important work upon the rocks at Ensay and Omeo, by Mr. A. W. Howitt, and published in the Proceedings of the Royal Society of Victoria, and in the Victorian Departmental publications.

north. From one pit only twenty feet deep and about 7 feet long he obtained 100 ounces of gold from specimen quartz, and it is easy to see that by the denudation of a band of rock such as this lying nearly parallel to the average trend of the valley, these little pockets, even at some distance apart, would be ample to supply the alluvial gold.

The granitic area at Granite Flat is really one of a quartz diorite. The rock slide shows plagioclase felspar, green and brown hornblende, some mica in places, and pegmatitic quartz full of solid inclusions that are very minute and may be rutile. The area is traversed by fissure veins that seem generally to be small. Some of those that run in an east and west direction have copper pyrites as a lode filling, one that seemed larger than the average (*i.e.* that on the Empress of India lease) had copper pyrites, iron pyrites, quartz, carbonate of lime and gold, and a copper sulphide much resembling "glance" in appearance but not so rich as that mineral in copper. A full discussion of the occurrences would be, however, somewhat outside of the scope of this paper.

The area that is undoubtedly of metamorphic rocks includes the Little Snowy Creek. In this area there is a strip of country from Mount Elmo through Scrubby Creek, Lockhart's Gap and Bethanga, along which, at greater or less intervals, rich gold deposits are found. The deposits are not always in large lodes, and occasionally they are not in well marked ones, but this latter is the exception. The deposits are undoubtedly valuable from an economic point of view as well as interesting from the scientific one. Eastward of this series is one of tin occurrences that I have not been able personally to see *in situ*, but they appear to extend from a point a few miles eastward of Mount Elmo, to across the Mitta Mitta at Eskdale, and thence to Tallangatta and to the Murray River. The specimens that have reached me are all of greisen with cassiterite in very coarse crystals. The occurrences are doubtless isolated ones and so far have not been "proved" from an economic point of view, but this by no means indicates them to be worthless; indeed, the general want of knowledge locally as regards ore treatment prevents these tin deposits from being fairly tested at the present date.

Adverting, however, to the occurrences of gold, that at Mount Elmo will now be considered. The rocks amongst which it is found are quartzites with mica and andalusite schists, and these are associated with holocrystalline rocks, some of which are undoubted metamorphosed, whilst there are others about which some reserve must be made, but which will probably prove also to be of metamorphic character, and which appear to have been intrusions that already existed in the area prior to the period at which the change from shales to schists took place.

Mount Elmo lies about three miles south east by east of the trigonometrical survey station of Mount Towanga, and the field is reached from Eskdale by one of the new roads of the Mines Department following the western or main branch of the Little Snowy Creëk. The mines are upon several lines of reef, a considerable distance apart, two of which are at Mount Elmo, where they dip with and follow the ancient bedding planes of the country. The dip is 65 degrees east and the strike is about 10 degrees west of true north. The reefs at Mount Elmo have not yet been traced for a distance of more than about 1½ miles, and are, as far as prospected, cut off completely by the bands or masses of the holocrystalline rocks just mentioned. The author was not able to visit the mass at the southern end of the line of reef, but at the northern end, lying between the Little Snowy Creek and the mountain spur containing the reef outcrops themselves, the band is variable in character. One mass that he saw was a tourmaline rock with felspars and muscovite, whilst another showed upon slicing, felspar, muscovite and biotite, some quartz exhibiting much strain structure and containing small fibrous inclusions, probably sillimanite, light brown hornblende and tremolite.

The top of the mountain, somewhat to the eastward of the line of reef, is of greisen, a mass of which appears to lie parallel to the schists, but there was not an opportunity to trace out its extent.

The part of the mountain where the more westerly of the two reefs is exposed is an andalustic and mica schist, the andalusite crystals showing up very well upon the weathered surfaces on the mountain side. The reef lies between a dense impervious bed of black quartzite and a bed of andalusite schist of a few feet thickness, on the other side of which a second bed of the black impervious quartzite is found. These black quartzites are manifestly the remains of the old sandstones, and the andalusite schist that of old shales ; the partings between the two classes of rocks are still quite distinct. It may be here noted that the quartzite forms the hanging wall of the reef whilst the schist footwall has been distinctly affected and attacked by the filling of the reef. This reef is from six inches thick up to one foot six inches thick, and in the Lone Hand mine, where the author was able to examine it, had shown an almost continuous "shoot" of auriferous stone for three hundred feet, with values varying from a few pennyweights up to several ounces of gold per ton. One interesting feature here, as in the case at the Lightning Creek, is the parallelism of the auriferous deposit to the old bedding planes, but the case under notice shows in addition the controlling action of the hard quartzite beds upon the direction and concentration of the deposits, deposits doubtless initiated along the planes of weakness due to the dissimilar characters of the beds of schist and of quartzite and accentuated by metasomatic action when once started. The holocrystalline rocks at the ends of the beds have doubtless also acted as controlling factors, limiting the extent of the deposit, and it must remain for the present an interesting speculation as to how far gold was derived from them. Although there have been prospecting operations in many parts of the field, yet the useful deposit appears to lie wholly in the two reefs to which reference has just been made.

There are a number of small rich deposits at Scrubby Creek, near Tallandoon, that from the description given to the author may well correspond to the occurrence at Mount Elmo, but these he was unable to visit. Some of the specimens showed however galena to be present in the lode fillings.

At a point about three miles north westward of Lockhart's Gap there is another auriferous deposit of considerable extent lying not in a lode but in a band of holocrystalline metamorphic rock, showing idiomorphic quartz crystals and pegmatitic growth with the other constituents. It carries iron pyrites and free gold, the latter sometimes to a sufficient extent to make it a valuable gold ore, and its presence is itself sufficient to account for the fine alluvial gold along the creeks now being sluiced below it, just as in the case of the deposits at Lightning Creek.

The ore occurrence an Bethanga is one of very great interest in itself and was that to which most attention was paid for the purposes of the paper. The mines at Bethanga are upon several parallel lines of lode that have a general direction of 30 degrees east of north. One of these main lines and some subsidiary ones traverse the length of Mount Talgarno for nearly a mile, this portion of the mine the author could only examine on the surface.

At a point about half a mile to the eastward of the southern end of the first lode, there is a second one known as Conness' that continues southward past a bifurcation that occurs, and until it reaches a fault line running nearly east and west and which throws it about five chains eastward. Its continuation southward of the fault forms the Gift mine for a distance of about three thousand feet, but three hundred feet of this nearest to the fault is not yet opened. This mine has three shafts, the "Gift," "Martin's" and "Leighton's," in the order named, going southward, of which Martin's and Leighton's are the deepest, owing to the slope of the ground. Martin's shaft is 800 feet deep.

A third lode also, broken by the fault, lies about half a mile to the eastward of the Conness and Gift line—this lode has the Welcome mine in its northern end and the Excelsior mine in its southern portions respectively.

A careful inspection of the surface showed that these lodes were each in similar rocks typical of the district and this enabled the author to concentrate his attention on the Gift and Leighton mine where most work is in progress at the present time, and where an exposure 800 feet from the surface can be seen.

The whole of the district around the mine is of schistose and gneissic rocks, passing from manifest biotite and other schists, characterized by much contortion, into a holocrystalline rock or gneiss with the characteristic structure often resembling an intrusive one in the field, but which proves on slicing to be of oligoclase, biotite mica, very pale brown hornblende, some quartz showing much strain structure, garnets surrounded by chlorite and with very beautiful fibrolite, and small idiomorphic cordierite[1]—two typical slices are shown in Figures No. 1 and No. 2.

[1] Cordierite has recently been recorded as occurring at Wood's Point by F. P. Mennell —Geolog. Mag., Sept. 1902.

The association between the hornblende or with the chlorite and the fibrolite does not appear to be accidental. The lode track is in this rock mass, it follows the line of rock that is most completely metamorphosed, and although it is well defined, its filling is, apart from the mineral contents, essentially the same as the country, there is a little more quartz at some places and in a few others a hard chloritic "pug" impregnated with pyrites and presenting slickensides is found. The metallic minerals are arsenical and ordinary iron pyrites, and copper pyrites, all carrying gold. There are very few vughs, but where these occur they show crystalline quartz and calcite upon iron pyrites. The copper, but not the gold contents, increase toward the line of the east and west fault.

The analysis of the rock from several different places is shown in the table. Analysis (A) is of the rock adjacent to lode track in No. 2 level at the Gift shaft end, whilst analysis (B), (C), (D), are from samples collected along No. 5 cross cut (about 700 feet) on Martin's shaft. (B) being from near to the lode track, (D) from about 70 feet distance and (C) from a point intermediate between (B) and (D). The rock has however large segregation of oligoclase and small garnets, and no single analysis would fairly indicate its composition. Analysis (E) is of the felspar which is thus shown to be oligoclase.

	No. 2 Level	No. 5 Cross Cut			Felspar
Analysis	(A)	(B)	(C)	(D)	(E)
SiO_2	58.14	71.01	67.37	66.86	70.60
Al_2O_3	17.92	10.74	11.78	11.76	19.08
Fe_2O_3(and FeO)	12.71	5.19	5.43	6.72	trace
CaO	.65	3.36	2.50	1.02	2.94
MgO	.23	1.50	2.37	1.23	0.79
Na_2O	3.12	4.47	3.05	7.89	4.60
K_2O	3.02	2.38	3.81	3.86	1.78
P	.20	trace	.43	trace	—
S	nil	—	nil	—	—
Cl	.15	trace	trace	—	—
Water at 100°C.	.72	0.32	nil	0.67	—
Water above 100°C.	3.60	1.41	2.50	0.48	—
	100.46	100.38	99.24	100.49	99.79

The lodes are only of moderate average thickness say, of 1 foot and 1 foot 6 inches, but the contents are fairly rich, an average of 1½ ounce gold per ton has been obtained over a considerable period of working. The lode filling therefore shows a high grade of concentration.

The lode track is full of small slickensides, that are interesting when viewed in connection with the contorted schist of the neighbourhood, and to the regular and solid rock mass adjacent to it.

Referring now generally to the facts recorded as to Bethanga, Mount Elmo and Lightning Creek, it will be noticed that there is a parallelism of the strike of the deposit to the ancient bedding planes seen or inferred in each case, and, at the same time, the deposit is not of the "contact" class. This same parallelism is a marked feature of many of the deposits in the schists of the Western Coast of Tasmania, only there the deposits are prominently connected with metasomatic action, during which action the element fluorine has often been present in so much quantity as to bring about the production of minerals such as axinite, datolite, fluorite and tourmaline, to such an extent as to somewhat mask the original features. The same feature of parallelism is involved in the now generally accepted reading of the Broken Hill occurrence, as being an extreme case of a saddle information in schist, and, it is interesting in passing, to note that, at the latter place, Mr. J. C. Moulden[1] has recorded the presence of cordierite but as a primary constituent of the rock. Although the evidence, if not otherwise supported, would not be in itself strong, nevertheless, there is in it a considerable suggestion as to similarity of origin.

All the occurrences described in the paper have common features, but these features differ greatly in degree. The crystalline rocks or gneisses at Bethanga offer the extreme case of metamorphosis just as do the gneissose masses at Ensay or the crystalline schists at Broken Hill or in North Western Tasmania, and in addition to this they exhibit extreme concentration of mineral in a narrow lode track. The auriferous rocks at Mount Elmo exhibit both of the same phenomena to a much smaller degree, whilst the occur-

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1 Jour. Roy. Soc. N.S.W.

rence at Lightning Creek is but an instance of the diffuse charging of schistose rocks with auriferous material. In the case of Lockhart's Gap there is a diffuse charging of holocrystalline rocks with metalliferous minerals. In all these four cases the author would however submit that the action by which they received their gold was a comparatively deeply seated one, as indicated by the presence of quartz, a substance that is in all probability present in the particular form in which we find it in lodes owing to a comparatively elevated temperature of the water current that carried the other mineral matter in course of deposition.

These deposits thus differ in a very important manner from the auriferous sandstone reefs to which the author has elsewhere drawn attention[1] as occurring in Victoria, and that have distinctly received their gold when much nearer to the surface as is shown by the absence of quartz—that mineral when it occurs in such reefs being found quite independently of the gold, and offering no guide to the occurrence of the latter. The gold in this case, although in silurian sandstone, was probably deposited at a much less remote date than that of the occurrences forming the subject matter of the paper and probably in late tertiary times.

The rocks at Bethanga show the interesting case where extreme earth pressure and local yielding has, owing to the work thereby done upon the rock, given rise to a development of heat so considerable as to bring about softening and a subsequent recrystallization of the mass, an unstable condition of affairs that relieves the earth stress[2] at a distance at the expense of the place where the movement first starts, and which, when it occurs near to a volcanic vent, is, the author would submit, the cause of a flow of fluid lava and the explanation of many volcanic phenomena. In the case under notice at Bethanga temporary planes of weakness must be assumed to have been left that were disturbed again before the zone had completely cooled down to the average temperature corresponding to its depth. Such planes may indeed have been initially formed by the contraction of the

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1 "Some Auriferous Deposits," Report Australasian Assoc. Science, vol. viii. Melbourne Meeting, 1901, p. 227.

2 One place where such a state of strain in the strata is manifest at the present moment is at Hillgrove, N.S.W. See official N.S.W. Report on Hillgrove Gold Field by Andrews, 1901, p. 18.

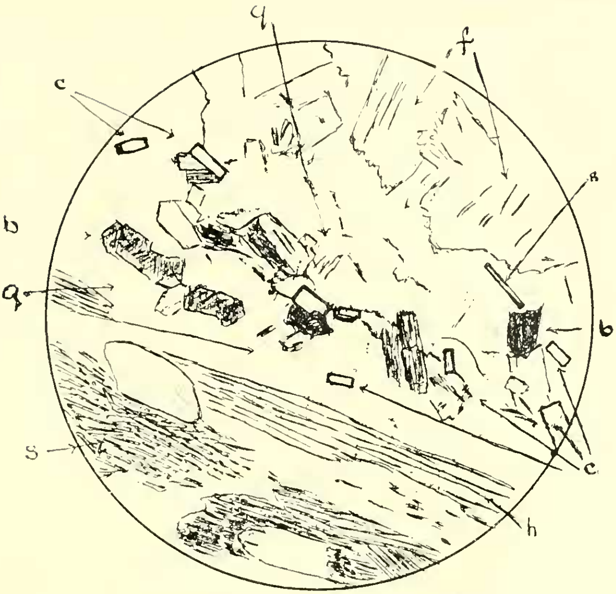
cooling mass after the original severe lateral pressure had been relieved, but this is a less likely explanation on several grounds. The planes of fracture would, in whatever way in which they were formed, become convenient courses at a later date for water currents in the earth to take, these would bring with them the minerals subequently deposited. The deposit has evidently not been completed at one period of time, for although there does not appear to have been the phenomenal surface enrichment of the lode seen on many of the Victorian fields, yet there is the enrichment of the lode in copper to be accounted for at the places adjacent to the main east and west fault plane.

At Mount Elmo the plane of weakness was evidently given by the still distinct bedding planes between the quartzites and schists whilst the two impervious beds of quartzite kept the subsequent water current to a definite course and with it the deposit. In the case of Lightning Creek, metamorphosis had not proceeded to so great an extent, and in the absence of dykes or fault planes the deep seated aqueous currents were not so confined—so that even though rich deposits of gold could and did occur they were individually smaller and generally more diffuse. Although in all probability belonging to the same period of time it presents the extreme opposite case to the concentration of mineral seen at Bethanga, owing to the different degree of permeability to aqueous currents that it possessed.

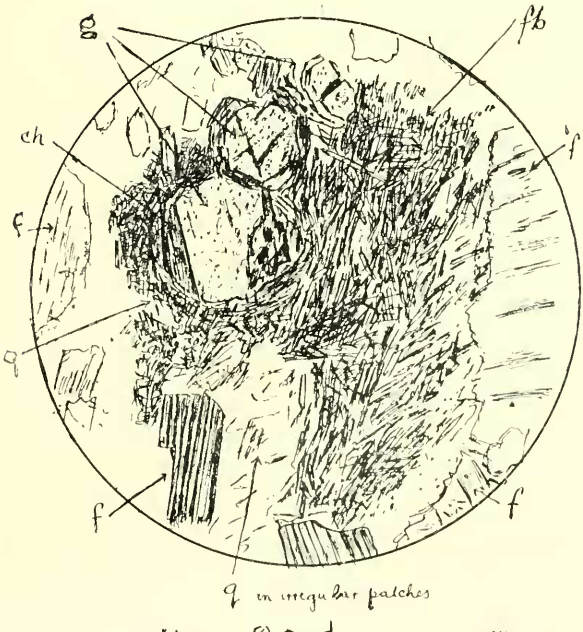
EXPLANATION OF PLATE I.

Fig. 1.—A typical section of the gneiss. There is hornblende (*h*) —pleochroism very pale yellow to pale brown, Sillimanite, (S)—occasionally as single inclusion in quartz, but more often occupying areas amongst the hornblende. Biotite Mica (*b*) Cordierite (*c*) generally as simple prismatic crystals grouped and single and lying amongst biotite or in quartz (*q*) this latter showing much strain figure in polarized light. The felspar (*f*) are both of twinned and simple areas.

Fig. 2.—Is an actual section taken from one of the felspathic aggregations in the gneiss in the lower part of mine. There are garnets (*g*) each more or less completely



N × 40 d Fig. 1.



N × 20 d Fig. 2.